IRON ORE PRODUCTION AT KIRKENES, NORWAY

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ABSTRACT

Location.

Kirkenes is a seaport on Varanger Fjord, North Norway, a few kilometres from the Soviet Boundary. Despite its high latitude (69°44' N.) shipping continues throughout the year. The port was built in 1906 for exporting iron ore from the mine at Bjørnevatn, about 10 km. inland.

Significance and early development.

The Kirkenes iron ore, a taconite with a metallic content of about 30%, can be marketed profitably because it is mined economically by open-cast methods, is close to the seaport and can be shipped direct to overseas markets in Europe where there is a steady demand. The ore itself is not easy to mine or process. It occurs as metamorphosed sediments, with magnetite and quartz forming an extremely hard banded taconite, underlain and overlain by gneiss. Deposits cover a large area surrounding the main deposit at Bjørnevatn.

Production began in 1910 following about four years construction work. Early in World War I exports had reached about 550,000 m. tons of concentrates and briquettes a year. In 1937, shortly before the Second World War, the rate had reached 700,000 m. tons. About 1600 men were employed in the work and Kirkenes had grown to be a town of 4500 people with another 1500 at Bjørnevatn.

This growth is remarkable when it is recalled that the mine was a pioneer undertaking in every way. The location was remote and almost unpopulated, and the technical problems of processing extremely hard taconite with a low metal content had not then been solved elsewhere.

Destruction and rebuilding.

During 1942-44 Kirkenes was almost obliterated by bombing during its occupation by Nazi forces. When the invaders were finally driven out, they systematically devastated what remained of the mine workings, the concentrator and the towns. Following the war the Company determined to modernize the operation completely with the aid of the Norwegian government which provided about two-thirds of the necessary capital. New mining methods were devised and a completely new concentrating plant and new shipping facilities were built. Dollars were provided from Marshall Funds for purchase of some equipment in the United States.

The new plant is designed to process about 2.3 million tons of ore a year, equivalent to about 1 million tons of concentrate containing about 66% metal.

Operations.

Ore is mined by drilling vertical holes and blasting out the rock in "benches." About 0.5 tons of waste is removed for each ton of ore. After preliminary crushing at the mine, the ore is conveyed by an electric railway almost 10 km. to the concentrator near the seacoast at Kirkenes. Following a complex process of crushing, grinding,

sorting, filtering and drying, a very fine black powder results. Eventually up to 50% of this will be formed into pellets but at present it is shipped in powder form. From a storage silo holding 70,000 tons, this finished product is carried underground by conveyor belts to the quay where it is loaded directly into vessels by conveyor belts hauling about 1,000 tons per hour. Vessels of up to 15,000 tons can be berthed at the quays.

The mine reopened in April, 1952, and ore was first shipped the following month. By the end of 1952 a little over 400,000 tons of concentrate had been produced, almost all of which was shipped at once. The total export for 1953 was about 830,000 tons. As in prewar years, most of the ore is shipped to West Germany, with other shipments going to the United Kingdom and Belgium.

Power sources.

The most convenient source of electricity for mine and concentrator, would be waterfalls on the Pasvik River. As this forms the boundary with USSR the water power cannot at present be developed. Several small hydro plants have been erected on other streams, but the majority of the power used is provided by a steam plant at Kirkenes using Svalbard coal. Salt water for washing and fresh water for steam are readily available.

Significance to Norway.

The Kirkenes plant is important for several reasons:

(1) It provides foreign exchange from export of iron ore.

(2) The economy of northern Norway, otherwise largely dependent on fish, is strengthened.

(3) Norwegian mining and other equipment designed for use with Kirkenes taconite can secure a foreign market.

I. Locational factors.

Kirkenes is a Norwegian iron ore port on the southern side of Varanger Fjord close to the Norwegian-Soviet border. Its latitude, 69°44'N, is roughly equivalent to that of Disko Bay, Greenland or Point Hope, Alaska, and its longitude, 30°03'E, places it due north of Alexandria, Egypt. Kirkenes lies about 220 miles north of the Arctic Circle and 130 miles farther north than the better known mining town of Kiruna in Sweden. Distances to Kirkenes by sea are a significant factor since practically all its freight and passenger traffic moves by ship. Typical distances are:

Kirkenes to:	Oslo, Norway	1,450 miles
	Newcastle, England	1,500 miles
	Hamburg, Germany	1,600 miles
	Boston, Mass., U.S.A.	4,150 miles

The sole justification for Kirkenes as a well-equipped seaport and settlement of about 3,800 people is the occurrence a few miles inland of large iron ore deposits.

The northerly location of Kirkenes may give a misleading impression of the severity of the local climate and the harshness of conditions under which mining, shipping and living goes on. In fact, the Kirkenes climate is surprisingly mild. A statistical summary appears as Appendix A. The main characteristics of the climate are:- mean monthly temperatures which range from about 11°F. in February to about 53°F. in August. Extreme temperatures range from an average low of -25°F. to a high of 78°F. On an average the daily mean rises above 32°F. on May 1 and sinks again below it on October 17. Precipitation is comparatively light, the annual total being about 16.2 in. with a summer maximum. Snow covers the ground on an average of 180 days in the year, the area usually being snow-free from early May through September. The mean depth of snow, in January through March, when it is greatest, is about 16 in. The climate at Kirkenes is of course influenced by its location on Varanger Fjord. Stations even a few miles inland have more severe conditions -- with the warmer summers and cooler winters typical of less maritime conditions.

Length of daylight, an important factor in mining and shipping operations, has a direct effect on the seasonal demand for electrical power and influences the daily lives of local residents. The long winter night in such latitudes is, however, not as great a factor as is often supposed. Thus, although the sun does not rise at Kirkenes from the last day of November to January 14th, the period when there is complete darkness for the twenty-four hours is of course much shorter than this. Thus "twilight" never falls below four hours a day even in mid-winter, and the sun does not set from mid-May to July 24. There are in all about 108 days with at least twilight throughout the night.[1]

Although navigation is open throughout the winter at Kirkenes, this is made possible by the use of a small ice-breaker. While the open sea does not freeze[2] the fresher water near the head of fjords and other inlets would do so if left undisturbed. The mining com-

pany at present uses a converted whale-catcher, about 130 ft. long as combined ice-breaker and local pilot boat. This vessel is to be replaced by a properly designed ice-breaker, of about the same size. Vessels using the harbour need not be constructed to navigate ice. Freshwater lakes in the neighbourhood freeze as does the Pasvik River. The fact that seawater temperatures are relatively low in summer and close to freezing in winter is an asset since the water is used in steam condensers in the Kirkenes electrical power plant.

Kirkenes is remote from large centres of population and commerce. It is not connected to the European rail network, and in winter the gravel highway which links it to southern Norway (Route 50) is blocked by snow at several points. The sole all-year connection with the outer world is therefore by sea, and the town and the iron ore mine must depend on the sea for all their needs, apart from small amounts of food and lumber produced locally. Commercial airlines link Kirkenes with southern Norway from about April to October.3/

II. Location and occurrence of iron ore deposits.

The iron ore exported from Kirkenes occurs on a peninsula between a long narrow arm of the sea (Langfjord) on the west and the valley of the Pasvik River on the east, and from 100 to 170 metres above sea level. (See Fig. 3.) The area of the whold field is about 7 miles by 3 miles, and includes several distinct sites. Present workings are in a limited area about 5 miles south of Kirkenes, near a lake, Bjørnevatn (Bear Lake) which gives its name to the nearby mining settlement.

The mining company holds title to an area about 13 miles by 3 miles, which includes the ore fields, Bjørnevatn (the mining settlement) and most of the Kirkenes townsite.

The mine is within sight of Soviet territory about 2 miles to the east.4/ When standing on a hill not far from the mine, it is possible to see, fifteen miles to the south, the tall chimney of the Soviet nickel smelter at Nikkeli, and the lights of the two mining settlements can readily be seen from each other in winter. It was while searching for an extension of the Bjørnevatn iron ore fields across the international border in what was then Finland, that the nickel deposits were discovered in the early 1920's.

The Bjørnevatn ore occurs5/ as metamorphosed sediments of middle Precambrian (Karelian formation) age in an area which has been intensely folded. The ore itself is overlain and underlain by gneisses. The series is bounded in some directions by faults and elsewhere by granite. The ore now being worked is in a steeply dipping fold cut by faulting and intruded by dykes. It forms a rough V-shape, pointing northward. As the map shows (Fig. 4), the width of ore varies greatly. The area exposed by the present open pit covers 3/4 miles by 1/2 mile. An intensive program og geological exploration is continuing in an effort to outline accurately the extent of the various deposits, as a preliminary to planning long-range mining operations.6/

The Bjørnevatn ore now being mined is extremely hard magnetite inter-laminated with quartz with a relatively low iron content and

resembles closely the Minnesota taconites.7/ A typical specimen shows from 34-37% of total iron. About 30-32% is magnetite and about 44% quartz. The sulphur and phosphorus content is extremely low. When compared with the Minnesota taconites, the ore is slightly richer in magnetite and somewhat more crystalline. However, the two are so similar that experience gained in operating the Norwegian field can be applied directly to the benefit of taconite mining in the United States.

From a production viewpoint, the chief problems to be faced in mining and processing the Bjørnevatn ore for export are:

1. Drilling the ore and the surrounding rock preparatory to blasting it. The ore is extremely hard and the nine inch diameter holes can only be driven about five feet into the ore before the bit needs to be replaced.8/ In making a hole ready for blasting, only about 15 feet can be drilled in a typical 8 hour shift.

2. There is difficulty in breaking the large ore blocks blasted loose into sizes that can be handled by the primary crusher which needs to be exceptionally heavy to crush the ore.

3. In concentrating the ore to increase the content of iron and remove as much waste as possible, the problem is to extract the fine particles of magnetite from among the quartz. This requires a complex process of crushing, grinding, separating, washing, drying and so on.

III. Historical outline of mining near Kirkenes.

When one considers the many technical problems to be faced in producing a marketable product from the Kirkenes taconites, it is remarkable to recall that the operation began almost 50 years ago. Nowhere else in the world have such apparently unprepossessing ores been worked with such success over a long period of years.

The mining company "Aktieselskabet Sydvaranger" (named from the local term for the land south of Varanger Fjord) was founded in 1906 to work ores which had first been located in the late 60's of the previous century.9/ The initiative and most of the early capital came from Sweden, but the head office was in Oslo and the company has always been Norwegian. The building of harbour works, the concentrator and other plant began at Kirkenes in 1907, but it was not until 1910 that the first fine black powder -- or "slig" as it is termed in Norwegian -- was produced. There were many technical difficulties in the early years, particularly with the equipment used to blast, crush and grind the hard ore, and the product, a fine powder mixed with a certain amount of water, proved a difficult cargo to ship.10/

Additional finances were provided for the company by Hamburg bankers in 1908 and there has been a close contact with Germany ever since. Today much of the concentrate is shipped to West German blast furnaces. The First World War brought financial troubles to the company due to the Allied blockade of German ports, and the post-war years were also difficult, but by the late 1930's Sydvaranger had again achieved a strong position, and in 1939, at the end of the first era of Kirkenes mining, an impressive record had been

achieved. A stock-taking at that time would have revealed something like the following:

About 25 million tons of ore had been mined, and shipped in the form of 10.4 million tons of concentrates (averaging 66-67% iron, 7% silica, .009% phosphorus, .008% sulphur). Of this total about half (5.3 million tons) had been exported in the form of briquettes containing about 65% iron. The rest had been shipped as powder. The briquettes had gone mainly to Britain and the powdered concentrate to western European countries, mainly Germany. The annual rate of production had in 1939 exceeded 800,000 tons of concentrate, representing about 1,900,000 tons of ore mined. In all Kr.215 million had been received for the product. This impressive record was set up, it needs to be recalled, in an extremely remote and undeveloped locality previously occupied by a few Lapp and Norwegian fishermen. By 1939, the company had about 1,700 employees, and Kirkenes and Bjørnevatn were well-built and prosperous communities totalling about 7,000 persons.[11]

The Second World War led not only to disruption of mining and ore shipments, but eventually brought about the almost complete destruction of the mining and processing equipment. The town of Kirkenes and all other settlements in the area were almost obliterated by 1945. The occupying Nazi forces converted Kirkenes into a stronghold, heavily manned and armed, a base for naval operations and starting point for air attacks on north Russian convoys. As a consequence, it was very heavily bombed by the Allies, and in the early winter of 1944 what remained was almost completely destroyed by Nazi armies as they retreated westward.[12]

When the war ended, the mining company was confronted with an industry that had in effect been wiped out. To operate again, it would need complete reconstruction. Settlements at Kirkenes and Bjørnevatn, railroads, docks and all the complex plant built up since the company's founding would have to be rebuilt. If, on the other hand, the undertaking was of doubtful economic worth under modern conditions, its destruction provided an opportunity to withdraw from the area for good. One valuable asset the company had: the experience and skill accumulated by its technical staff in the previous forty years. Sydvaranger had unique knowledge of how to mine and process taconites and to do so in a remote and somewhat unfriendly physical environment. Any decision about the economic feasibility of the undertaking would hinge mainly on the long term export market for the product, since Norway at the time had no iron smelting industry needing such large tonnages of ore.

IV. Postwar reconstruction and expansion.

The future of Kirkenes mining obviously depended on securing a market for the product. Fortunately this was not difficult. Customers, both in Britain and on the continent, were ready to purchase the whole output of concentrate, immediately after the war. Thanks to direct ocean transport from concentrator almost to consumer, and the negligible rail transport from mine to shipping point, the Kirkenes product could reach European industrial markets at competitive and even premium prices. To meet the requirements of ore users,

however, a proportion of the Sydvaranger product would need to be exported as briquettes or pellets.[13]

Any plans for the future would of course depend on the extent of good quality ore reserves, their accessibility and the cost of extraction and processing. Assuming adequate reserves, the technical problems of mining and processing would still remain to be solved. The original mining and concentrating equipment installed in 1910 had been ultra-modern, and had been gradually modified as new techniques were devised. But this existing plant, or rather what was left of it in 1945, would need replacement. Finally there was the question of finance. To erect a plant capable of reaching even the pre-war output would require an estimated Kr. 125 million (about $25,000,000), a very large sum in Norway at a time when other devastated areas farther south also needed reconstruction.

This last problem was eventually solved by a happy compromise between private and public financing under which the government subscribed about 60% of the necessary capital,[14] while leaving the actual operation of the undertaking to a semi-independent board of directors. The dollar currency needed to secure special equipment from the United States, was made available through Marshall Aid of $5,000,000.[15] Some other factors needing consideration were more problematical. Labour had always been something of a difficulty; in fact the output from the plant in pre-war years had been roughly in proportion to the labour supply available. The industry employed about 1,300 men in 1939 but the labour force had largely dispersed when operations ceased during the war, and less than 200 remained in 1944. There were few reasons why a new group of skilled workers Should accept jobs "at the far end of the country,"[16] at the end of an expensive transportation route and where living conditions might be less attractive than in the south. Any plans for reopening the plant should, if possible, use a reduced labour force, provide attractive living conditions, and do everything possible to re-establish a sound community of well-qualified and contented people.

Systematic exploration of the ore fields begun in 1946, confirmed the existence of ample reserves, and still more ore has been discovered since. Following work done in the 1953 summer, it was stated[17] that about 4,000 additional metres of test drilling at the Bjørnevatn mine had outlined more than 50,000,000 tons of ore and the work was continuing. Apart from this ore occurrence, there are others in the vicinity which can be opened up when needed.

When work at the mine recommenced in 1950, a new operation plan was used, based on continuing use of open-pit methods, instead of changing to underground mining as had originally been intended. Under the new plan, open-pit working will continue for about the next fifteen years. In the following ten years underground workings will gradually be introduced so that probably by 1975 mining will be completely underground. The reasons behind this change in technique are interesting. The present bottom of the open pit is on an average about 82 metres above sea level, although at one point it is only 66 metres above sea level. At the southern end of the pit is a lake (Bjørnevatn), whose surface is about 81 metres above sea level. (See Fig. 4) This is to be drained through a 2.5 km. long

tunnel driven in from Langfjord.[18] Draining the lake will expose additional ore for open-pit mining, will provide space for dumping waste rock and will prevent seepage into underground workings. The open pit will eventually be carried down to 30 metres below sea level, at which time underground mining will become necessary, as mentioned above. Economic considerations lie behind these plans. It is estimated that about 45 million tons of ore can be extracted with removal of about 20 million tons of waste rock. Open mining will cease when the ratio between the two becomes 1 : 1, i.e. when a ton of waste must be removed for every ton of ore. Open mining is preferred for many reasons. It requires only 2/3 of the labour force, permits greater and more flexible use of machinery, and planning and operation of the work is simpler. At first sight an apparent objection to it is the winter climate. This has not proved a serious handicap in the past. Temperatures are less extreme than those in the Minnesota iron-mining area, although the winter is longer. Snowfall is relatively light and has proved to be an advantage as snow and ice provide and excellent surface for the heavy haulage vehicles, reducing wear and tear on the tires. Working lights are needed for 24 hours a day in winter but the long period of daylight in summer offers some compensation.

An additional factor in favour of open-pit mining has been the development, largely in the United States, of very heavy ore-moving equipment such as shovels and trucks. Electric shovels now in use can load 4½ cubic years of ore at a time, into 35 ton carriers.[19] These and other vehicles are able to operate over mine roads of about 8% grade, which is much steeper than was possible with the locomotives employed in the old mine. Hence the open pit can be carried to a far greater depth.

Certain considerations of a political-economic sort also favoured reopening of the Sydvaranger mine after the war. Finnmark, the northernmost county in Norway has long been a "distress area." Seasonal unemployment in fishing and farming has been chronic. Economic backwardness at a distance from the centre of government in Oslo has tended to encourage radical political beliefs based on supposed neglect. The rise in power of the Soviet Union, whose territory is adjacent to Finnmark made this problem even more acute. Furthermore the area is clearly not unimportant in North Atlantic defence strategy. In the immediate post-war years the Norwegian government was for these and other reasons determined to expand the economy of North Norway. The aim was to provide a broader economic base by encouraging mining and other industries in order to provide a market for local products and to maintain more regular employment. While some of the projects which formed a part of a coordinated North Norway Plan[20] could only mature over a long period of years, Sydvaranger mining could probably revive the derelict local economy relatively quickly. This explains in part the readiness of the government to provide capital for the company and a high priority in securing new equipment.

When the decision to proceed with reconstruction was made in 1946, plans were laid out for completely new mine and processing plants. These new plans called for the use of more mechanical power, a reduction in man-power, and some increase in output.

V. Processing the ore.

The processes needed to mine Bjørnevatn ore and convert it into a finished product ready for shipment are, in outline, these:

The ore must be blasted out from the open pit, and larger blocks broken by further blasting. The ore has then to be broken down in a crusher to a size suitable for transfer by railroad to Kirkenes. There it needs further crushing and grinding to a fine powder, the magnetite must be separated from waste rock, the product dried and formed into briquettes or pellets and loaded into the vessel for shipment. At various stages conveyors are needed to transfer material from one point to another, as well as storage bins of various sizes, classifiers to sort the products and so on. The waste rock must also be disposed of.

a. The original plant.

The original plant was elaborate and ingenious, but as a pioneer undertaking, it proved after 30 years to be less efficient than it could be. There were for example thirty-two separate sets of units operating side by side at the concentrator -- in effect thirty-two separate plants, all of small capacity.[21] They needed close supervision by a large staff of workmen, and maintenance was expensive. The so-called "briquettes" which formed about half of the end-product, were in fact massive conical blocks of concentrate, each weighing 44 pounds (20 kilos). These too needed individual attention. The final product was excellent, as less than 3% of the magnetite found in the original ore was lost. The concentrate when ready for shipment consisted of 91.5% magnetite, 6% quartz and 2.5% other materials. To this was added 5-7% water when it was shipped as powder.

In addition to supplies of ore, the plant needed electricity for its many operations, water in large amounts, steel balls and rock pebbles for the mills as well as countless other supplies. In converting each 2.3 tons of ore into a ton of concentrate, about 45 kWh of electricity were used. The source of most of this was a steam plant at Kirkenes, using coal imported from Britain, Poland and Germany. Furthermore, each ton of ore needed 4½ tons of seawater while being processed. In addition fresh water was needed for steam making, etc. For securing water the plant was well-located between the sea on the north and a string of three small lakes on the south.

b. The new plant.

In outline, the modern processing of the ore is as follows:

Holes, nine inches in diameter are drilled vertically into the ore, and a carefully calculated charge of powder is placed in them. The ore is then blasted out in "benches" about 44 feet high. The ore blocks are loaded by electrically-powered tracked shovels into the large trucks already mentioned, and carried to the crusher. Bulldozers clean up the smaller pieces of ore, and a grader works full time maintaining good road surfaces. As it is cheaper to crush large blocks of ore than to drill and blast them into pieces, one of the

world's heaviest ore crushers, designed to A/S Sydvaranger's specifications but built by Nordberg in Milwaukee, Wisconsin, has been installed at the Bjørnevatn mine. Weighing about 500 tons, it is able to take blocks of ore up to 54 in. in size, [22] and can handle up to 2,000 tons of ore each hour. To withstand the enormous stresses involved in crushing the very hard ore to a size no larger than 6 in., the main shaft of the rotary crusher was made 50 ins. in diameter and weighs 100 tons. A constant problem with such an enormous crusher is to dispose of the heat generated. About 100 gallons of oil per minute circulate in this machine serving both as lubricant and cooling agent. Incidentally, the cold winter climate is in this case an advantage, since the oil cools naturally. When the crusher is idle in winter some heating is needed.

From the crusher the ore drops into a bin from which it is discharged on to a conveyor belt. This underground conveyor, 42 inches wide, runs for about 850 feet at an angle of 15½° rising about 225 feet to the top of a 10,000 ton ore bin excavated in the solid rock.[23] Standard guage railroad tracks run under this main storage bin. Trains of about 12, 40-ton cars, hauled by an electric locomotive carry the ore the 5½ miles to Kirkenes. In this way about 200,000 tons a month are transported year-round. As is to be expected there is some trouble from ore freezing into the cars in winter.

Subsequent treatment of the ore at Kirkenes is not complex in principle, although it is difficult to carry out in practice. The ore must be crushed to smaller size, and then transferred to a ball mill where it is ground with about 80 tons of 5 inches diameter steel balls. These balls are of course gradually worn away, but in the process the ore is ground to particles of about 1/20 mm. in size. It is at this stage that large amounts of seawater are added requiring a flow of up to 30 cu. metres a minute. The finer particles of ore are separated from the larger by screening, and the heavy pulp of ore and water is passed over a series of rubber-coated magnetite drums[24] which attract the magnetite but allow the waste rock to escape. This waste is carried, still mixed with water, through a tunnel to be dumped in Langfjord. Powerful vacuum filters then extract most of the water from the concentrated magnetite, which is finally dried in heated kilns until it contains 5-7% water.

In the pre-war plant part of the final product was made into large briquettes by the "filter-briquetting" method developed by the company. At present (1954) the whole product of the new mill is sold as powder. However, work has started on a series of furnaces to be used in making pellets -- small balls of concentrate about 10 mm. - 30 mm. in diameter, which are indurated by heating. Tests have shown that these are excellent for blast furnace use, since they withstand crushing. Pellet production should commence at Kirkenes in 1955. Initial production is to be 100,000 - 150,000 tons a year.[25] with capacity expanding to an estimated 500,000 tons a year.

The concentrate ready for export is carried by conveyors to a storage bin holding 70,000 tons, excavated in the cliff near the export quay.[26] Additional storage space is to be excavated so as to double that now available. The ore is carried to the ship's hold

on conveyor belts, as required, at a rate exceeding 1,000 tons an hour.[27] Vessels drawing 30 feet, and up to 15,000 tons can be accommodated at the wharves, but typical ore carriers are of about 10,000 tons.[28]

VI. Provision of electric power.

Electric power sufficient to handle the heavy demands of the mine, railroad and concentrator, as well as the lighting and power needs of various communities, has not been easy to provide.[29] Although Norway has a justified reputation for being a leader in hydro-electric development, the Kirkenes area is not particularly well endowed. The best nearby hydro power sites are waterfalls on the Pasvik River a few miles east of Kirkenes, but as the river forms the boundary between Norway and the USSR there seems no immediate possibility of it being harnessed.[30]

Beginning in 1920,[31] a small hydro plant was built at Tårnet about 15 miles northeast of Kirkenes where a 260 foot head of water is carried through a wooden-stave flume to generate about 1,000 kVA. (This old plant is shortly to be modernized.) A decade later, a second hydro plant was built at Kobholm on the seacoast 25 miles northeast of Kirkenes and only three miles from the international border. There a head of about 375 feet is carried through rock-cut tunnels to develop about 2,400 kVA. This latter plant can at present only be reached from Kirkenes by sea.

Since the Second World War, a third hydro electric plant has been built at Gandvik about 40 miles northwest of Kirkenes, by a publicly owned company. Of about 5,200 kVA capacity, this plant is primarily intended to serve local communities, but it also contracts to provide the mining company with 1,000 kVA. The Gandvik plant is linked to another publicly-owned plant at Kongsfjord. A third publicly-owned hydro plant is planned for Neiden 20 miles west of Kirkenes. To be of 7,500 kVA, it may provide some power for use by the mining company.

As has been the case since the mine opened in 1910, the main supply of electricity needed is generated at a steam turbine plant at Kirkenes itself. The present plant was opened in 1951. It has two generators which together produce about 18,750 kVA.[32] This is a completely modern and highly efficient installation. It has been found that Svalbard coal, despite its 10% ash content serves excellently. Because of the short shipping season, a 25,000 ton stockpile of coal is accumulated at Kirkenes in summer. Cooling of the steam condensers is done by pumping seawater which is always at a low temperature. The cooling water, now heated is pumped to the concentrator to be used in the ore concentrating processing.

In addition to supply the mining company, the two hydro plants and one steam plant also help to reduce the risk that communities in the area will be without power in case of a breakdown. The Company plants are inter-connected with the public system. Such a precaution is particularly necessary because of the long, dark winters and the isolation of the area from other sources of power.[33]

It should be emphasized that, not only in the supply of power, but in many other ways, the isolated Kirkenes region needs to be as self-sufficient as possible. The mining company maintains exceptionally large stores of spare parts, its repair shops are unusually well equipped and its workmen must be highly skilled and adaptable. Electrical equipment, mining machinery, locomotives and so on must be overhauled locally because of the delay and expense involved in shipping them the long distance to South Norway. There are, for example, local facilities for retreading the huge ore-truck tires, and for the manufacture of oxygen for welding.

VII. Production and shipping of concentrate.

The capacity of the Sydvaranger plant is about 2.3 million tons of ore per annum, equivalent to 1 million tons of the final product. Following remarkably speedy reconstruction, the first ore was shipped from the mine to Kirkenes in March, 1952, and the first concentrate left the port in mid-May en route to Barrow-in-Furness, England. By the end of 1952, exports totalled 397,843 of the 413,554 tons of concentrate produced. In December of that year 90,000 tons were exported, indicating a rate of about 1 million tons a year.34/ That year's shipment brought to Norway the equivalent of Kr. 36 million (about $5.1 million) all in much-needed "hard" currencies, mainly from West Germany and Britain, and a profit on the year's working of about 1.4 million kroner.35/ Assets of the company then totalled about Kr. 180 million. At this time the company employed 1,021 persons of whom 831 were workmen at Kirkenes and Bjørnevatn. This did not include temporary labour employed by construction companies. This promising beginning was maintained in 1953 when about 1,750,000 tons of ore were mined to produce very close to the 830,000 tons of concentrate planned. Gross income from selling the product abroad was about Kr. 55 million. Owing to lack of sufficient accommodation to stockpile concentrate in West-Germany, only 645,921 tons were actually shipped during the year, although the whole production had been sold in advance.36/ It was because of this delay in shipment that emergency stockpiles had to be made in the open air at Kirkenes. The 1953 export was shipped in 85 vessels going to 13 importers in Germany, Great Britain and Belgium. A small shipment of about 1,800 tons was sold in Norway.

Although the new plant has not yet reached its full planned production, it is clear from the production data (Appendix B) that a fairly large quantity of concentrate remains on hand at Kirkenes. The main reason for this (apart from the fall in steel production in West-Germany) is that the European market is not able to absorb 1 million tons of the very finely ground type of concentrate Kirkenes produces. Until 1940 a considerable part of the concentrate exported was in the form of briquettes37/ which were sold very largely to the United Kingdom. When the new Kirkenes pellet-making plant is in operation, beginning in 1955, this difficulty should be overcome, and it is expected that when 500,000 tons of pellets can be produced annually there will be no difficulty in disposing of the full 1 million tons of concentrate which the plant was designed to produce each year.

It is expected that about 800,000 tons of concentrate will be

produced in 1954 and that 700,000 tons will be exported.38/ In fact the company had contracted in advance to supply this amount to foreign purchasers.

A single shipment of 7,000 tons of concentrate was sent to the United States in August, 1952. Regular shipments to the United States would of course be particularly desirable since they would bring Norway dollars. Two reasons limit large regular shipments to the United States. One is the lack of surplus sintering capacity to handle the ore. This may be overcome when the pelletizing plant at Kirkenes is operating. The other reason is that ore prices, including freight, are somewhat lower in the United States than in Europe. Before 1940 some concentrate went to Poland and Czechoslovakia, but none had been shipped from the new plant.

VIII. Conclusion.

The reconstructed Sydvaranger enterprise -- which literally arose from the ashes -- has already brought new life to a region extending south from Kirkenes into the Pasvik Valley and east and west along the southern shore of Varanger Fjord. Before the war Kirkenes itself had a population of about 4,500 with another 1,500 people living at Bjørnevatn, and a total of about 10,000 in the area as a whole, more or less dependent on the mine. In 1944 the economic basis of the region had all but disappeared -- and with it many of the people. There was very real hesitation as to whether reconstruction of the plant and rebuilding of these various communities could economically be justified.

Today, early in 1954, Kirkenes is approaching complete reconstruction39/ and other settlements in the neighbourhood are well on the way to being rebuilt. There seems good reason to believe that the mining industry will prosper and may well expand its capacity. Kirkenes mining company makes a handsome contribution to the Norwegian economy, since it represents at present about 1/6 of the country's mining production, and accounts for perhaps 80% of Norway's iron ore exports, and more than 50% of the value of minerals from North Norway's three provinces. Kirkenes furthermore provides an important terminal point on the express shipping route linking ports along the coast of Norway with Oslo. It attracts very many tourists every year, and is strategically important vis-à-vis the Soviet Union and the Barents Sea.

While there is a natural desire at present to export as much Sydvaranger concentrate as possible so as to secure foreign exchange, shipments will be diverted to supply material for the new nationally owned iron and steel plant at Mo i Rana some distance to the south, which will start operation in 1955, until the local mines are operating.40/

Among the many aspects of Sydvaranger iron ore production that are of interest to the student of natural resources utilization, one is outstanding. In that comparatively remote spot, a combination of Norwegian, Swedish and German enterprise has during almost half a century built up an efficient system for producing and marketing iron

ore concentrates from one of the most intractable ores known. In doing so, pioneer work in mining and processing has produced techniques and equipment likely to prove very useful in other areas where taconites are about to be utilized.

FOOTNOTES

1/ For details see Den Norske Los (Norwegian Pilot), Hefte X, Oslo. An interesting study of the effects of winter darkness on living conditions at Tromsø, Norway (Lat. 69°39'N.), is Kleitman, Nathaniel and Hortense, "The Sleep-wakefulness Pattern in the Arctic," Scientific Monthly, Vol. LXXVII, No. 3, Sept., 1953. But see also the important note added by William G. Metcalf to emphasize the importance of twilight at this latitude.

2/ Mean annual temperature of the sea at this point is 4°C., monthly means vary from 2°C. in January to 8°C. in August. Frogner, E., "Means and Extremes of Sea Temperature near the Norwegian Coast," Geofys. Publik., Vol. XV, No. 3, Oslo, 1948.

3/ A subsequent report in this series is to deal with transportation in Finnmark.

4/ The political geography of the international boundary is discussed in Lloyd, Trevor, "The Norwegian-Soviet Boundary, a Study in Political Geography," Hanover, N.H., 1954.

5/ The most recent geological studies of the area are by Dr. Jens Bugge. His main conclusions are summarized in Johanssen, J. Kraft, "Aktieselskabet Sydvaranger," Tids. for Kjemi, Bergvesen og Metallurgi, Nr. 26, March, 1950, pp. 1-10.

6/ An interim report on work in 1953 appears in an interview with J. Kraft Johanssen in Sør-Varanger Avis, Jan. 23, 1954.

7/ For a comparative analysis of three Minnesota taconites with that from Kirkenes, see Bugge, Jens A.W., "Sydvaranger Geology," Mining World, Vol. 15, No. 11, Oct., 1953, pp. 52-53.

For recent reports of progress toward mining U.S. taconites see:-
Data sheets on Pilotac and Extaca, Oliver Mining Division, U.S. Steel Corp. Mimeo. 1953.
"New industry grows from Taconite," Monthly Review, Federal Reserve Bank of Minneapolis, Feb., 1953, 14 pp.
"Messabi's answer to the iron ore shortage," Iron Age, Vol. 171, March 12, 1953, pp. 127-34.
"More iron from Minnesota's lean ores," Eng. and Min. Jour., Vol. 154, Oct., 1953, pp. 88-90.
"Report on Taconite," Steelways, Vol. 9, No. 5, Oct., 1953, pp. 1-5.
"Taconite processing - E.W. Davis works at East Beaver Bay," Construction Bulletin, Dec. 3, 1953, 7 pp.
"Erie ready to start work on big taconite project," Eng. and Min. Jour., Vol. 155, Jan., 1954, pp. 78-79.
Knowles, C.R., "Minnesota Taconite Developments" in Facts about Minnesota Mining, Iron Mining Industry of Minnesota, Duluth, Minn., Jan., 1954.

8/ Bits are sharpened as many as 80 times before being discarded. There is a specially equipped shop for this work at the mine.

9/ A useful summary of the early history is: Lundh, Carl, "Selskapets Stiftelse og Første År," Sør-Varanger Avis, No. 28, April 9, 1952, p. 9.

10/ A vessel leaving Kirkenes with the first shipment in 1910 foundered somewhere near the North Cape, apparently due to the cargo shifting, and causing it to turn turtle.

11/ Data from discussions and correspondence with officials. Johanssen, op. cit., p. 1, provides a short historical summary.

12/ The Nazi in charge, General Lothar Rendulic, has published a full account of his activities in the area, under the title of "Gekämpft - Gesiegt - Geschlagen," published at Wiesbaden, Germany in 1953.

Norwegians who suffered from the Nazi occupation and final "scorched earth" policy have published a record of those years as: Hellesnes, B.R. (Ed.), Finnmark i Flammer, 2 vols., Kragerø And Trondheim, 1949 and 1950.

13/ This is a somewhat technical but important consideration. Before the late war, Sydvaranger could sell an average of 750,000 tons a year by agglomerating some of the finely-ground concentrate, to make it suitable for direct use in blast furnaces. The powdered concentrate has to be "sintered" by the importer before it can be used in the blast furnace. It so happens that West Germany has larger sintering capacity in relation to its ore consumption than has Britain, and so is able to process a larger part of the fine Sydvaranger concentrate locally, hence markets for Sydvaranger concentrate are governed by the importer's sintering capacity, unless the product can be formed into briquettes or pellets at Kirkenes. This problem also faces taconite producers in the United States and explains the efforts being made to devise a suitable pelletizing process.

14/ Before World War II, 43% of the capital of A/S Sydvaranger had been German-owned. This capital automatically became Norwegian government property at the war's end.

15/ Details of the company's financing are given in Årsberetning (Annual Report), A/S Sydvaranger, 1952, Oslo, 1953.

16/ The journey from Oslo to Kirkenes is equivalent in distance to that from Oslo to Albania, or from Boston, Mass. to Ungava Bay, Canada.

17/ Tromsø, Jan. 27, 1954. For details of the drilling program and a summary of results, see Bugge, Jens A.W., op.cit., 1953, pp. 52-53.

18/ Press interview with J. Kraft Johanssen in Sør-Varanger Avis, Jan. 23, 1954.

19/ In 1953 the mine used 20 trucks of 22-35 ton capacity. Some mines elsewhere now use shovels with buckets of 6 cu. yard capacity and some engineers favour 7½ yard buckets on big jobs.

20/ For a complete description of the plan see St. meld. nr. 85 (1951), Utbyggingsprogrammet for Nord-Norge (Development program for North Norway.)

The economic outlook for iron-ore exporters in Europe was uncertain in 1946. Private capital would have hesitated to embark on a large-scale enterprise such as reconstructin A/S Sydvaranger's plant required. In the light of this, government action became very important.

21/ See Fig. 2. "Flowsheet for the old crushing and concentrating plants," in Johanssen, J. Kraft, "Iron Ore Concentration at Sydvaranger, Norway, Journal of the Iron and Steel Institute, Vol. 162, 1949, p. 4.

22/ The building which houses the crusher has been made large enough to take a second machine should this prove necessary.

23/ This and other aspects of the mine at Bjørnevatn are shown in Fig. 4.

24/ The new plant has greatly simplified the concentrating process by reducing the number of machines employed. For a recent discussion of this and other types of equipment used in processing taconite ores see DeVaney, Fred D., "Iron ore beneficiation; New taconite projects now assured," Eng. and Min. Jour., Vol. 155, No. 2, Feb., 1954, pp. 123-5.

25/ Sør-Varanger Avis, Jan. 23, 1954.

26/ When export of ore to Germany was temporarily delayed during the 1953-54 winter an additional 200,000 tons was stored in the open air at Kirkenes.

27/ Five men control equipment which has handled 1,140 tons and hour, so that ships arriving in the morning are loaded ready to sail in the afternoon.

28/ A/S Sydvaranger operates only one ore carrier, a vessel of 7,800 tons, registered at Kirkenes. German importers provide their own tonnage, but Britain and Belgium do not.

29/ Power shortages have been common in eastern Finnmark in recent years and rationing of the available supply has been necessary. See for example Finnmark Tidende, July 11, 1953.

30/ For details of delimitation and demarcation of the boundary see Lloyd, Trevor, op.cit., 1954.

31/ This and other power plants referred to are owned by Sydvaranger Kraftaktieselskap, a wholly owned subsidiary of A/S Sydvaranger.

32/ Technical details are given in Borsting, Asbjørn, "The Sydvaranger Story: Electric Power," Mining World, Vol. 15, No. 11, Oct., 1953, pp. 69-72.

33/ In spite of this precaution eastern Finnmark suffered serious shortage in 1953. The main transformer at the publicly-owned Gandvik plant broke down and about two months were needed to repair it. Meanwhile one of the two Kongsfjord generators was out of service. The mining company could not make up all the deficiency of power.

34/ There is no constant relationship between the amount of concentrate produced each month, and that shipped. A summary of production statistics is given in Appendices B and C.

35/ Financial details are provided in the company's Annual Reports e.g. Årsberetning for 1952, Oslo, 1953 and Årsberetning for 1953, Oslo, 1954.

36/ Steel production in West Germany during 1953 was less than had been anticipated when the ore was contracted for in 1952.

37/ Data in Appendices B and C.

38/ During the first 3 months of 1954, 188,500 tons of concentrate were produced, 164,450 tons being exported. Harstad Tidende, April 7, 1954.

39/ Fig. 8 shows the progress of reconstruction of the town and its relationship to the Sydvaranger plant.

40/ There is some question about the wisdom of using the premiun priced Sydvaranger product for this purpose if cheaper ores are available elsewhere. See Bøckman, K.C., "Bergverksdriften i Nord-Norge," Studieselskapet for Nord-Norsk Næringsliv, Skrift Nr. 5, Bodø, 1949, especially p. 4.

This point was also raised in the local Kirkenes press. See Sør-Varanger Avis, April 14, 1954.

APPENDIX A.

Summary of Climate Data for Kirkenes, Norway.[1]

(Height above sea level, 5m.)

Temperature.

Mean temperature 1874-1933 °C.

J	F	M	A	M	J	J	A	S	O	N	D	Year
-10.1	-10.6	-7.5	-2.0	3.0	8.0	11.9	10.8	6.7	0.3	-5.4	-8.8	-0.3

((There has been a small but appreciable change in these figures in the present century. The annual mean for 1901-1930 was 0.0°C., and that for 1916-1935 was still higher (1.1°C.) due largely to an increase in summer temperature.))

Mean maximum 25.7°C.

Mean minimum -31.6°C.

Av. date on which mean daily temp. first exceeds 0°C.....May 1.
Av. date on which mean daily temp. first falls below 0°C...Oct. 17.

Precipitation.

Mean precipitation 1901-30 in mm. of water.

J	F	M	A	M	J	J	A	S	O	N	D	Total
19	20	20	16	20	34	48	35	39	36	32	29	348 [2]

Mean monthly depth of snow in mm.

37	44	44	23	2	-	-	-	-	1	13	18	

No. of days with snow cover: - 180.

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[1] Temperatures from:

Geofysiske Publikasjoner, Oslo, Birkeland, B.J., "Mittel und Extreme der Lufttemperature," 1936.

Hesselberg, Th. und Birkeland, B.J., "Säkulare schwankungen des Klimas von Norwegen," 1940.

Precipitation from:

Nedbøren i Norge, 1895-1943, Det Norske Meteorologiske Institutt, Oslo, 1949.

[2] Equivalent to 13.65 in.

Appendix B.

PRODUCTION AND EXPORT OF IRON ORE, KIRKENES, NORWAY.

Five year averages 1910-1939 (♦).

	Number of Workmen	Mined ore (tons)	Concentrate (tons)	From which produced		Shipped (tons)
				Briquettes (tons)	Sinter (tons)	
1910-14	Insufficient Data	668,090	277,900	133,650		234,014
1915-19	840	655,812	224,800	117,660		176,800
1920-24	833	313,508	157,100	96,816	80,425 (*)	232,080
1925-29	567	726,280	323,740	138,740	Insufficient Data	330,599
1930-34	672	914,800	398,500	196,800		389,287
1935-39	1,180	1,651,220	704,520	369,060		724,620
Total Tonnage 1910-39		24,649,552	10,422,800	5,262,730	434,850 (**)	10,436,990

(♦) Computed from annual statistics provided by A/S Sydvaranger, Oslo: letter of March 9, 1954.

(*) Four-year average as no information is available for 1920.

(**) Total based on years, 1921-26, only.

Appendix C.

PRODUCTION AND EXPORT OF IRON ORE, KIRKENES, NORWAY.

1940-1953. (/)

	Number of Workmen	Mined ore (tons)	Concentrate (tons)	From which produced		Shipped (tons)	
				Briquettes (tons)	Sinter (tons)		
1940	928	783,000	356,300	130,400		180,776	1940
1941	753	705,600	323,300			167,792	1941
1942	626	45,600	8,800			301,722	1942
1943	642					171,290	1943
1944	192	85,650	39,700			50,196	1944
1945	312						1945
1946	335						1946
1947	446						1947
1948	572						1948
1949	590						1949
1950	644						1950
1951	754						1951
1952	831	934,300	413,554			397,843	1952
1953	821	1,747,100	832,962			645,921	1953

(/) Provided by A/S Sydvaranger, Oslo: letter of March 9th, 1954.

Appendix D.

SELECTED REFERENCES

The following publications were used in preparation of the report. Press clippings from local Norwegian newspapers proved a valuable source of recent information.

A/S Sydvaranger, Årsberetninger (Annual Reports), 1952, 1953, Oslo, 1953, 1954. Provide financial data on company operations and brief statement of production and export of ore, construction and future plans.

Birkeland, B.J., "Mittel und Extreme der Lufttemperatur," Geofys. Publik., Oslo, 1936. Air temperature data for many Norwegian stations, with maps and commentary.

Borgen, Axel, "Sør-Varanger og A/S Sydvaranger," Sør-Varanger Avis, April 9, 1952, pp. 17, 18, 23, 24, 25. Historical account of growth of the Kirkenes community and parallel development of iron mining, by a local resident.

Borsting, Asbjørn, "The Sydvaranger Story: Electric Power," Mining World, Vol. 15, No. 11, Oct., 1953, pp. 69-72. Technical account of electric generation and distribution in mine and mill, by the Chief Electrical Engineer.

Bugge, Jens A.W., "Sydvaranger Geology," Mining World, Vol. 15, No. 11, Oct., 1953, pp. 52-53. Summary of present knowledge, based on recent exploration, by company geologist.

Bøckman, K.C., "Bergverksdriften i Nord-Norge," Studieselskapet for Nord-Norsk Næringsliv, Skrift Nr. 5, Bodø, 1949. Summary of important mining operations in North Norway, with some reference to Sydvaranger.

DeVaney, Fred D., "Iron ore beneficiation; New taconite projects now assured," Eng. and Min. Jour., Vol. 155, No. 2, Feb., 1954, pp. 123-5. American techniques for processing iron ore concentrate.

Digre, Marcus, "The Sydvaranger Story: Milling," Mining World, Vol. [illegible], No. 11, Oct., 1953, pp. 60-62. Technical account of concentration of Bjørnevatn ore at Kirkenes.

Finnmark Tidende, Vadsø, Norway. (Twice weekly newspaper.) Various issues, 1951-54.

Frogner, E., "Means and Extremes of Sea Temperatures near the Norwegian Coast," Geofys. Publik., Vol. XV, No. 3, Oslo, 1948. Statistics and some maps, accompanied by commentary.

Harstad Tidende, Harstad, Norway. (Daily newspaper.) Various issues, 1951-54.

Hellesnes, B.R. (Ed.), Finnmark i Flammer, 2 vols., Kragerø and Trondheim, 1949 and 1950. Account by local residents of Nazi destruction in northern Norway and the 1944-45 evacuation.

Hesselberg, Th. and Birkeland, B.J., "Säkulare schwankungen des Klimas von Norwegen," Geofys. Publik., Oslo, 1940. Statistics with commentary.

Johanssen, J. Kraft, "Iron Ore Concentration at Sydvaranger, Norway," Journal of the Iron and Steel Institute, Vol. 162, No. 11, p. 4, etc., London, 1949. Comprehensive summary of the pre-war plant with description of plans for reconstruction.

Johanssen, J. Kraft, "Aktieselskabet Sydvaranger," Tids. for Kjemi, Bergvesen og Metallurgi, Nr. 26, pp. 1-10, Oslo, March, 1950. Similar to the above but with slightly more recent data.

Lloyd, Trevor, "The Norwegian-Soviet Boundary, A Study in Political Geography," Technical Report, ONR, 438-03-01, Hanover, N.H., 1954. Study of the Pasvik and Jakobselv valleys from the viewpoint of the Norwegian-Soviet Boundary.

Lund, Worm, "Agglomeration of Taconite Concentrate," Journal of the Iron and Steel Institute, Vol. 162, No. 11, London, 1949, p. 1. Technical account of proposed method of converting powdered concentrate into pellets, by a Sydvaranger engineer.

Lundh, Carl, "Selskapets (A/S Sydvaranger) Stiftelse og Første År," Sør-Varanger Avis, No. 28, April 9, 1952, p. 9. Historical account of A/S Sydvaranger operations.

Meyer, Ulf Smith, "The Sydvaranger Story: Mining," Mining World, Vol. 15, No. 11, Oct., 1953, pp. 54-57. Technical description of mining at Bjørnevatn.

Norge: Handelsdepartementet, "Utbyggingsprogrammet for Nord-Norge," St.meld. nr. 85 (1951). Official account of the programme of reconstruction and expansion of industry in northern Norway. Published by the government as a state paper.

Norge: Statistisk Sentralbyrå, "Månedsoppgaver over Vareomsetningen med Utlandet" (Monthly Bulletin of External Trade), Norges Offisielle Statistikk, Oslo, 1953 and 1954.

———————————— "Norges Bergverksdrift, 1951" (Norway's Mining Industry, 1951), Norges Offisielle Statistikk, XI. 124, Oslo, 1953. Statistical summary with brief text.

Norges Sjøkartverk, Den Norske Los (Norwegian Pilot), Hefte X, Oslo 1936. Handbook for mariners. Although somewhat out of date, a very useful supplement to Norwegian hydrographic charts.

Norges Vassdrags- og Elektrisitetsvesen, Utbygd Vannkraft i Norge, with map, Oslo, 1946. Text, statistics and maps.

Norges Meteorologiske Institutt, Nedbøren i Norge 1895-1943, Oslo, 1949. Full statistical treatment accompanied by text.

Rendulic, Lothar, Gekampft-Gesiegt-Geschlagen, Wiesbaden, Germany, 1953. The memoirs of a Nazi General who was responsible for the occupation of northern Finland and Norway, and the "scorched earth" policy of 1944-45.

Stavang, Arne, "The Sydvaranger Story: Mill Control," Mining World,

Vol. 15, No. 11, Oct., 1953, pp. 67-68. Technical account of milling operations at Kirkenes.

Sør-Varanger Avis. (Twice weekly newspaper.) Special issue on A/S Sydvaranger, April 9, 1952. Also numerous other issues 1951-54. An extremely informative and well-edited local newspaper published at Kirkenes.

Tromsø, Tromsø, Norway. (Daily newspaper.) Various issues 1951-54.

Vogt, T., "Norwegian Mine Output Drops During German Occupation," Eng. and Min. Jour., Vol. 148, Oct., 1947, pp. 92-94. Summary statement of mining statistics during World War II.

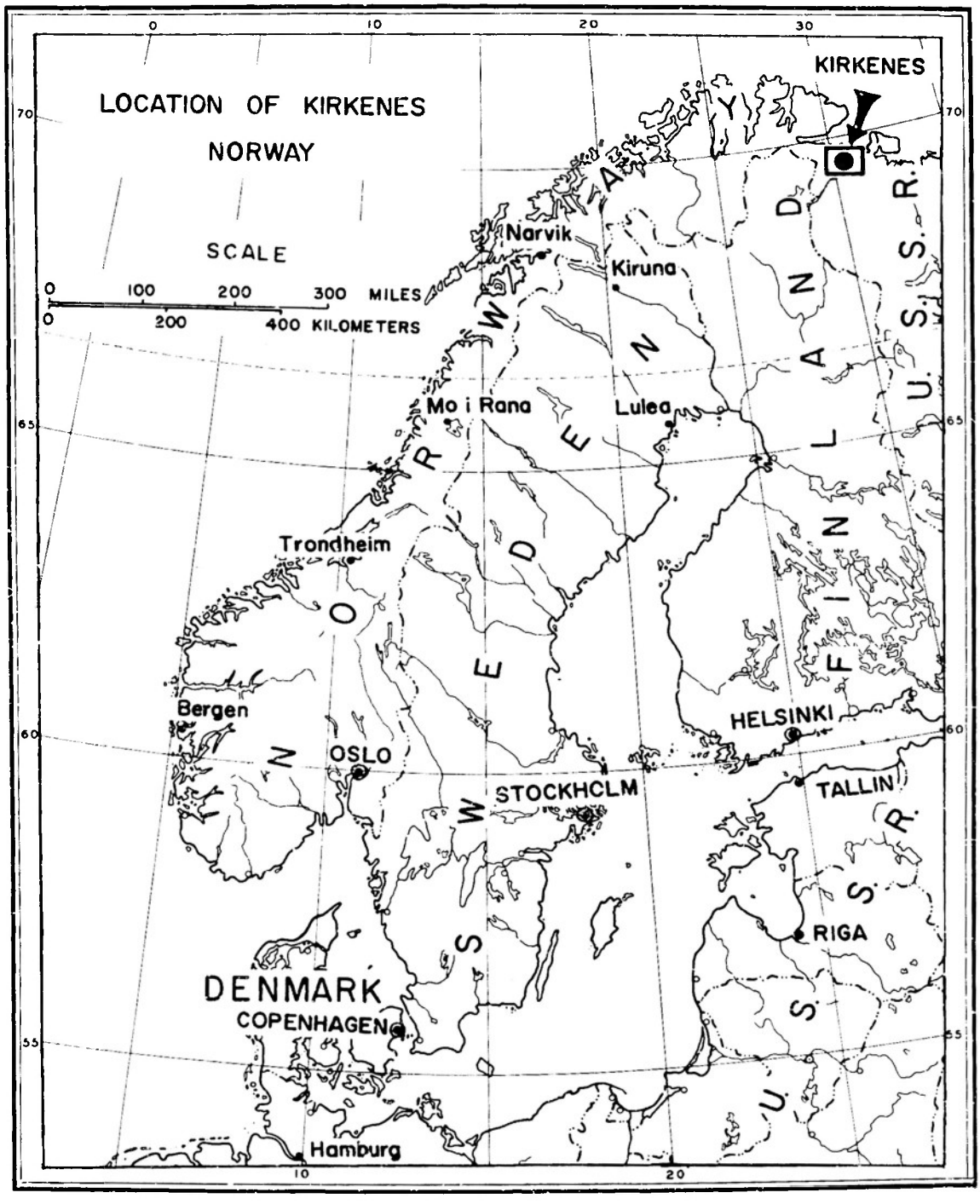
Anonymous.

"New industry grows from Taconite," Monthly Review, Federal Reserve Bank of Minneapolis, Feb., 1953, 14 pp.

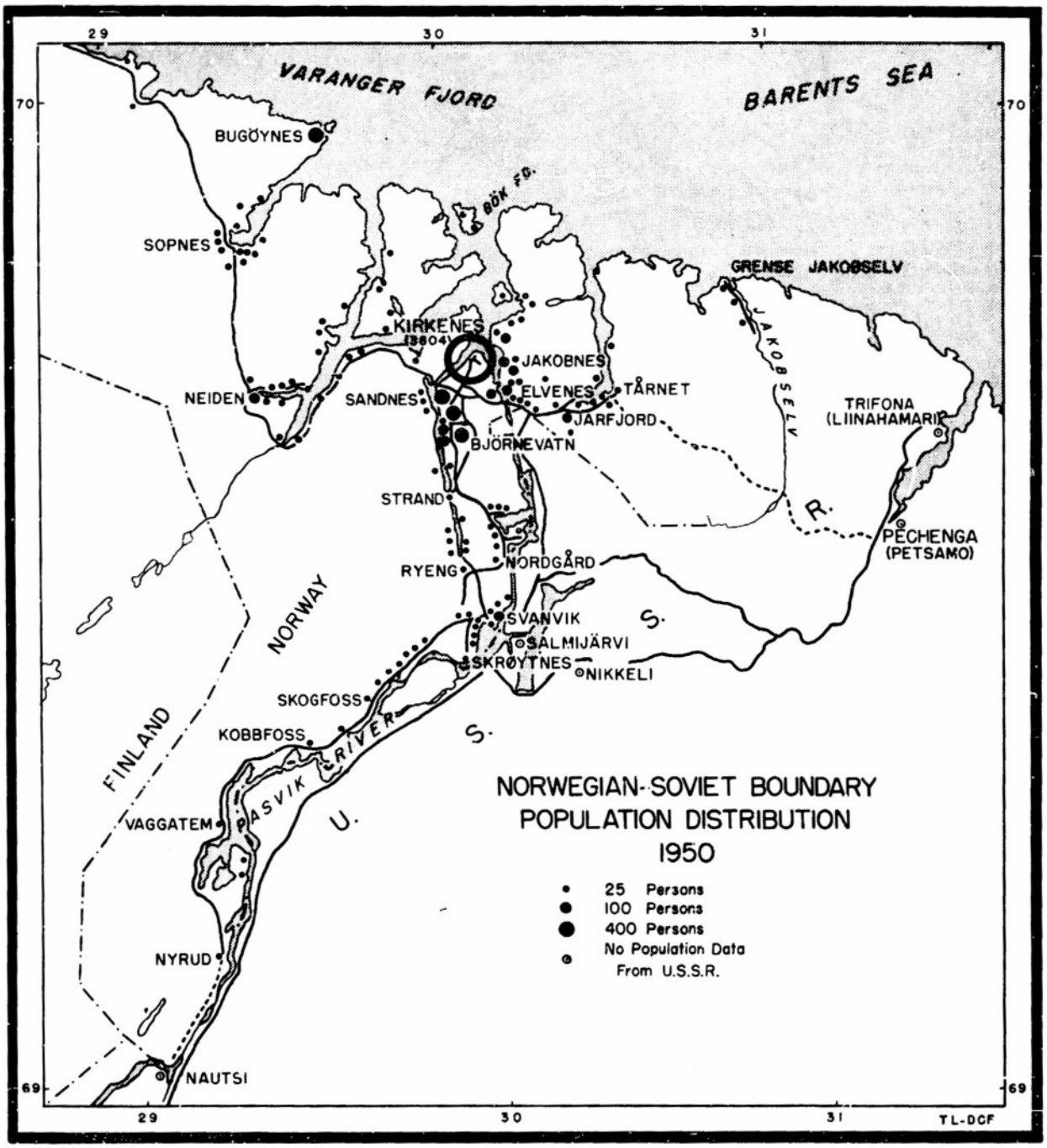
"Messabi's Answer to the iron ore shortage," Iron Age, Vol. 171, March 12, 1953, pp. 127-34. Progress in taconite mining.

"More ore from Minnesota's lean ores," Eng. and Min. Jour., Vol. 154, Oct., 1953, pp. 88-90. Report on taconite mining.

"Erie ready to start work on big taconite project," Eng. and Min. Jour., Vol. 155, Jan., 1954, pp. 78-79.


LOCATION OF KIRKENES
NORWAY
KIRKENES
SCALE
0 100 200 300 MILES
0 200 400 KILOMETERS
Narvik
Kiruna
Mo i Rana
Lulea
Trondheim
Bergen
OSLO
STOCKHCLM
HELSINKI
TALLIN
RIGA
COPENHAGEN
DENMARK
Hamburg
NORWEGIAN SEA
FINLAND
U.S.S.R.
0
10
20
30
70
65
60
55

Map 1


29
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31
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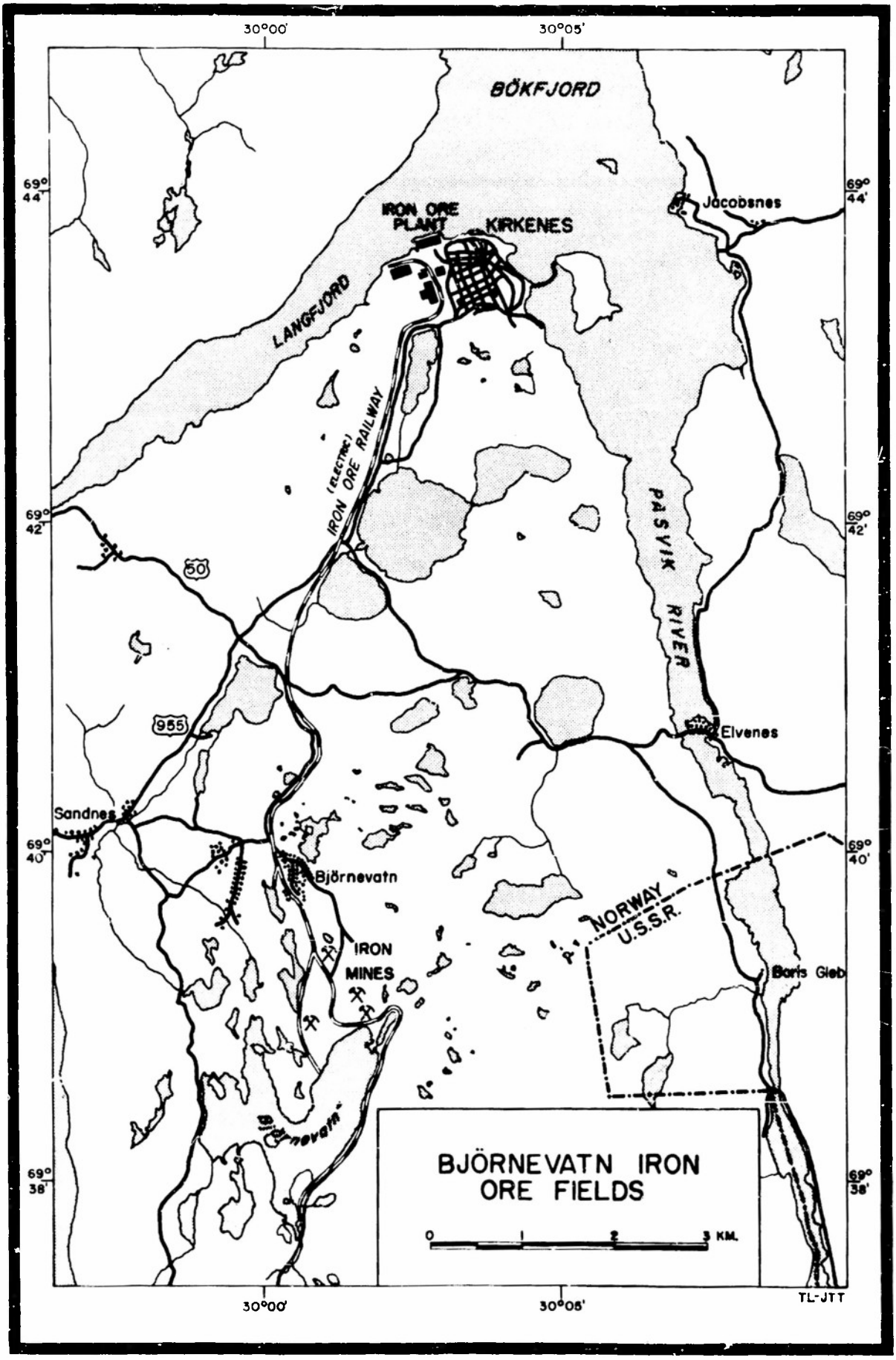
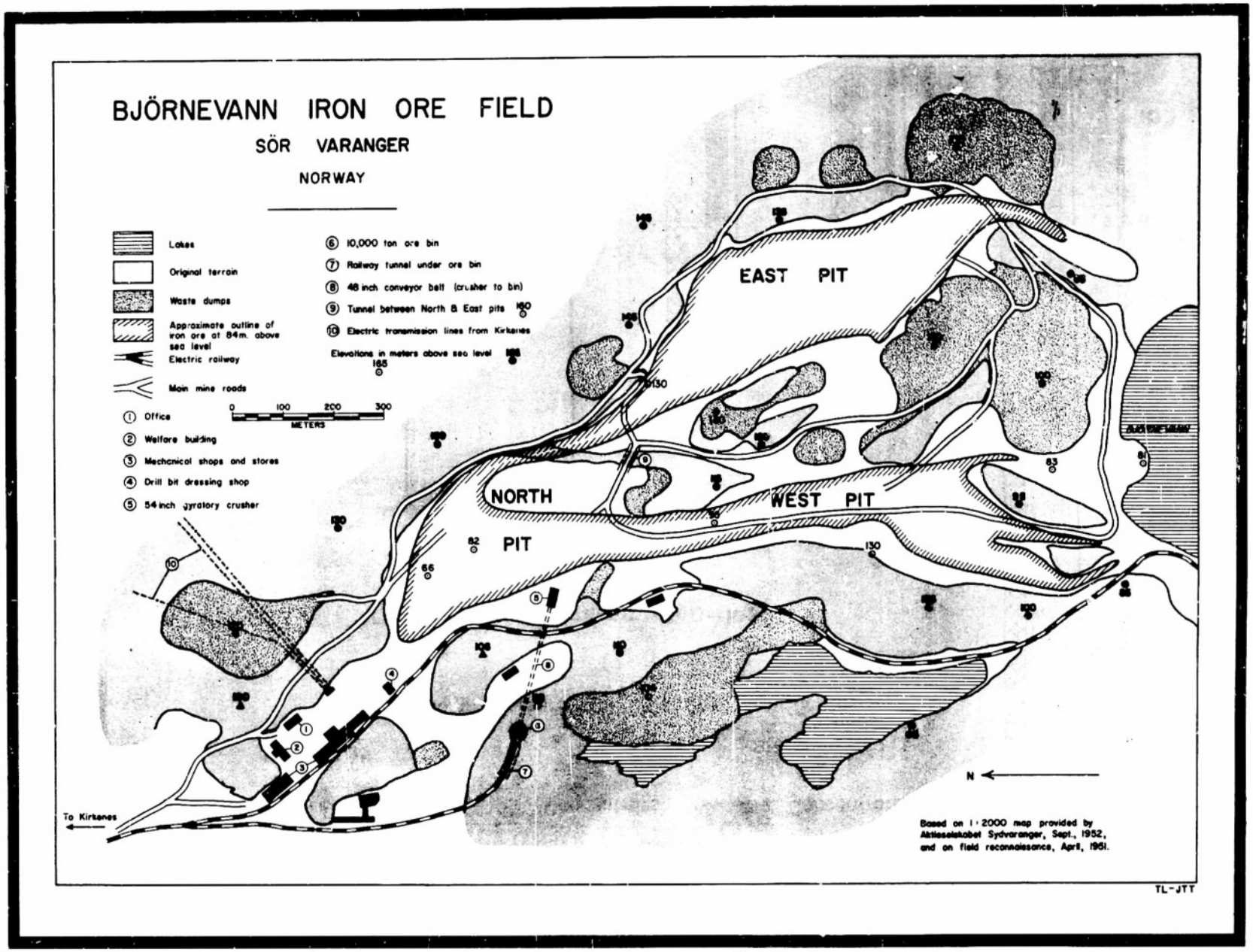
69
VARANGER FJORD
BARENTS SEA
BUGÖYNES
BÖK FD.
SOPNES
GRENSE JAKOBSELV
KIRKENES
13804
JAKOBNES
NEIDEN
SANDNES
ELVENES
TÅRNET
JARFJORD
TRIFONA
(LIINAHAMARI)
JAKOBSELV R.
BJÖRNEVATN
STRAND
PECHENGA
(PETSAMO)
RYENG
NORDGÅRD
NORWAY
SVANVIK
S.
SALMIJÄRVI
SKROYTNES
NIKKELI
SKOGFOSS
KOBBFOSS
FINLAND
PASVIK RIVER
S.
U.
VAGGATEM
NYRUD
NAUTSI
NORWEGIAN-SOVIET BOUNDARY
POPULATION DISTRIBUTION
1950
25 Persons
100 Persons
400 Persons
No Population Data
From U.S.S.R.
TL-DCF

Map 2


30°00'
30°05'
BÖKFJORD
69° 44'
IRON ORE PLANT
KIRKENES
Jacobsnes
LANGFJORD
IRON ORE RAILWAY (ELECTRIC)
69° 42'
PASVIK RIVER
50
955
Elvenes
Sandnes
69° 40'
Björnevatn
NORWAY
U.S.S.R.
IRON MINES
Boris Gleb
69° 38'
BJÖRNEVATN IRON ORE FIELDS
0 1 2 3 KM.
TL-JTT

Map 3


BJÖRNEVANN IRON ORE FIELD
SÖR VARANGER
NORWAY
Lakes
Original terrain
Waste dumps
Approximate outline of iron ore at 84m. above sea level
Electric railway
Main mine roads
① Office
② Welfare building
③ Mechanical shops and stores
④ Drill bit dressing shop
⑤ 54 inch gyratory crusher
⑥ 10,000 ton ore bin
⑦ Railway tunnel under ore bin
⑧ 48 inch conveyor belt (crusher to bin)
⑨ Tunnel between North & East pits
⑩ Electric transmission lines from Kirkenes
Elevations in meters above sea level
0 100 200 300
METERS
EAST PIT
NORTH PIT
WEST PIT
To Kirkenes
N
Based on 1:2000 map provided by Aktieselskabet Sydvaranger, Sept., 1952, and on field reconnaissance, April, 1951.
TL-JTT

Map 4

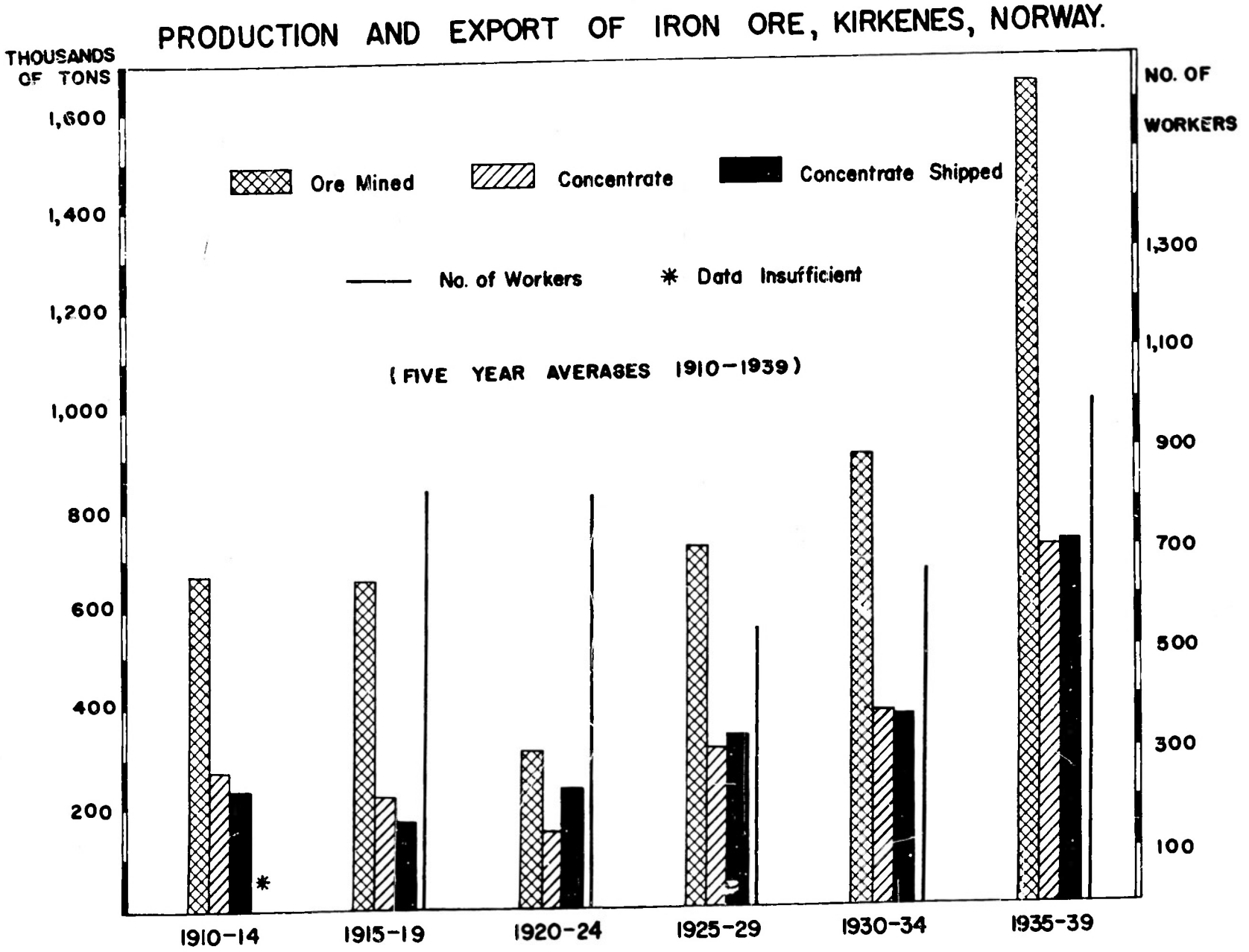
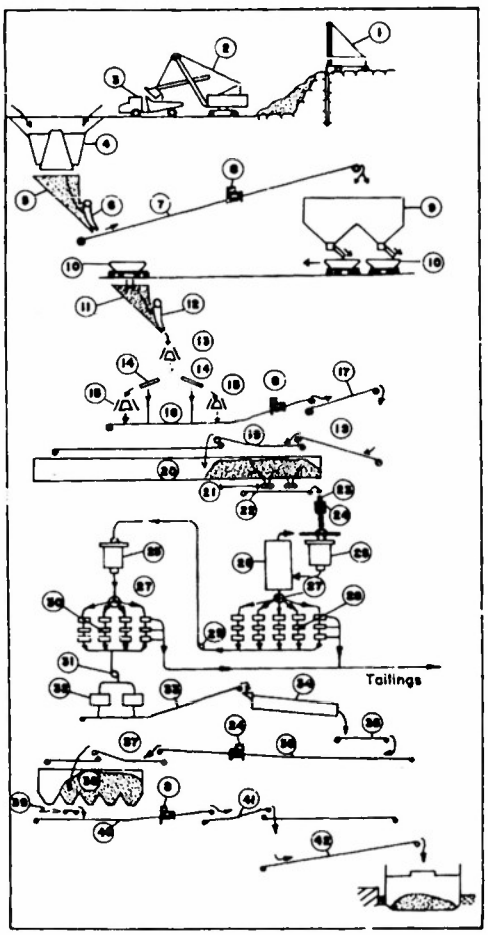

PRODUCTION AND EXPORT OF IRON ORE, KIRKENES, NORWAY.
THOUSANDS OF TONS
NO. OF WORKERS
1,600
1,400
1,200
1,000
800
600
400
200
1,300
1,100
900
700
500
300
100
Ore Mined
Concentrate
Concentrate Shipped
No. of Workers
* Data Insufficient
(FIVE YEAR AVERAGES 1910-1939)
1910-14
1915-19
1920-24
1925-29
1930-34
1935-39

Fig. 5

Ore Flow Diagram Bjornevatn Open Pit Mine and Kirkenes Concentrator of A/S Sydvaranger



Bjornevatn

1. Churn drill, Bucyrus-Erie 42 T
2. Electric Shovels, Bucyrus-Erie 120-B, 4½ yard dippers
3. Haulage, 40-ton Tournarockers and 22-ton Euclids
4. Gyratory crusher, 54-inch Nordberg
5. 100 ton ore bin
6. Ross chain feeder, 60-inch
7. Conveyor belt, 42-inch by 910-feet
8. Merrick Weightometer
9. 10,000 ton crushed ore bin
10. 40-ton bottom dump railroad cars

Kirkenes

11. 5,000 ton primary ore bin
12. Ross 60-inch chain feeder (2 units in plant)
13. Seven-foot standard Symons cone crusher (2)
14. Symons Rod Deck screen with ⅜ inch openings (2)
15. Symons shorthead cone crushers. Set at ⅜ inch (4)
16. Conveyor belt, 42-inch by 600-feet
17. Conveyor belt, 42-inch by 112-feet
18. Conveyor belt, 42-inch by 250-feet
19. Conveyor belt, 42-inch by 430-feet
20. 10,000 ton fine ore storage bin
21. Hardinge constant weight feeders (24)
22. Conveyor belts, 42-inch
23. Ball mill feed conveyors, 24-inch
24. Merrick Weightometers (2)
25. Nordberg ball mills 10-foot 8-inch by 17-feet. Two primary and two secondary
26. Akins 78-inch Duplex Spiral classifiers (2)
27. Pulp distributors (4)
28. Magnetic separators, Sydvaranger design, Built by Thune. (30)
29. Four-inch Vacseal pumps (2)
30. Magnetic separators (24)
31. Four-inch Vacseal pumps (2)
32. Oliver drum filters 8 by 16 foot (5)
33. Concentrate conveyor, 24-inch
34. Ruggles-Cole dryer, 12.6 by 70 feet
35. Conveyor belt, 42-inch by 100-feet
36. Conveyor belt, 24-inch by 1,100-feet
37. Conveyor belt, 24-inch (2)
38. 10,000 ton concentrate storage bin
39. Moveable apron feeder (2)
40. Conveyor belt, 42-inch
41. Shuttle conveyor belt, 42-inch
42. Ship loading conveyor, 42-inch

Fig. 6

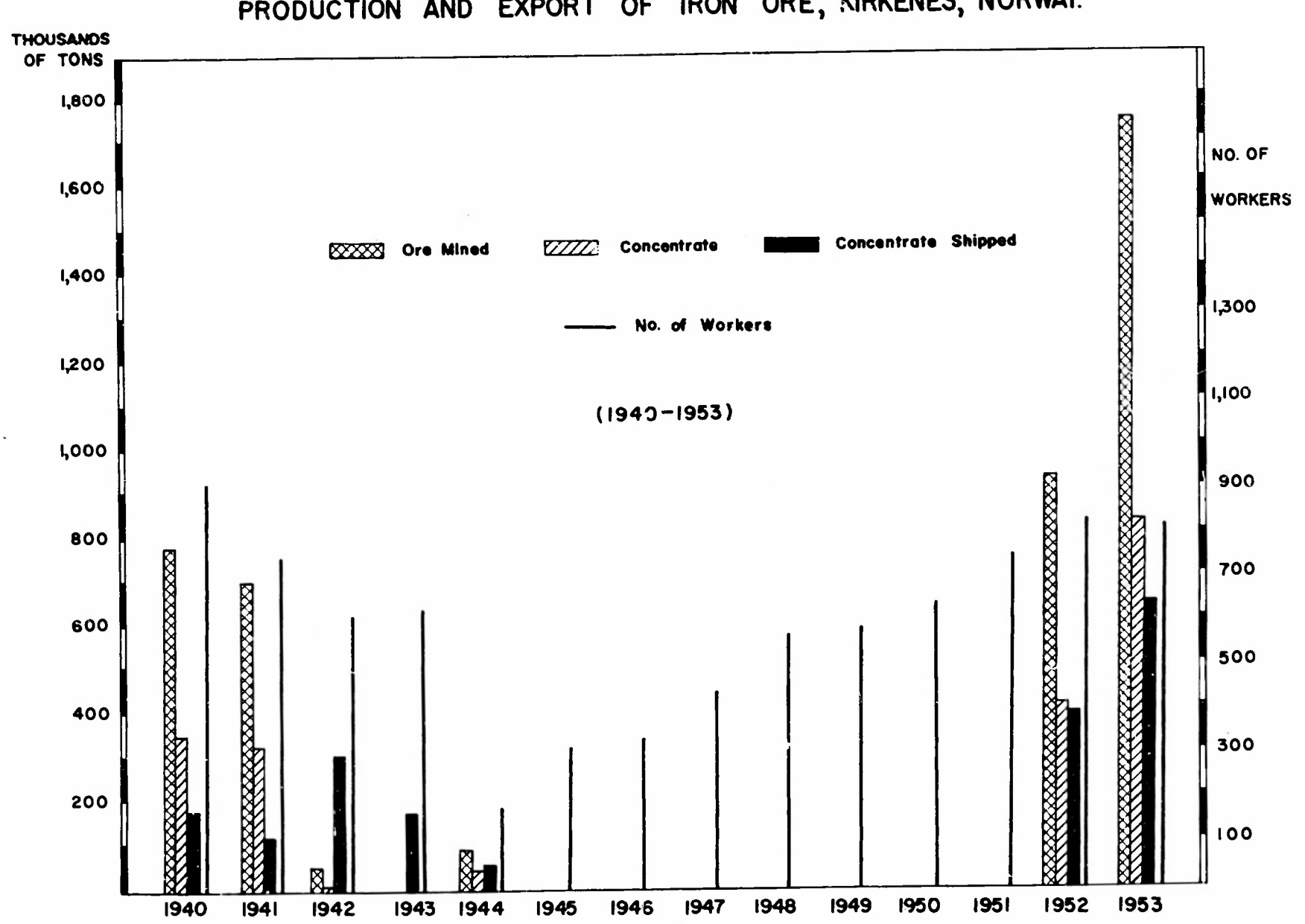
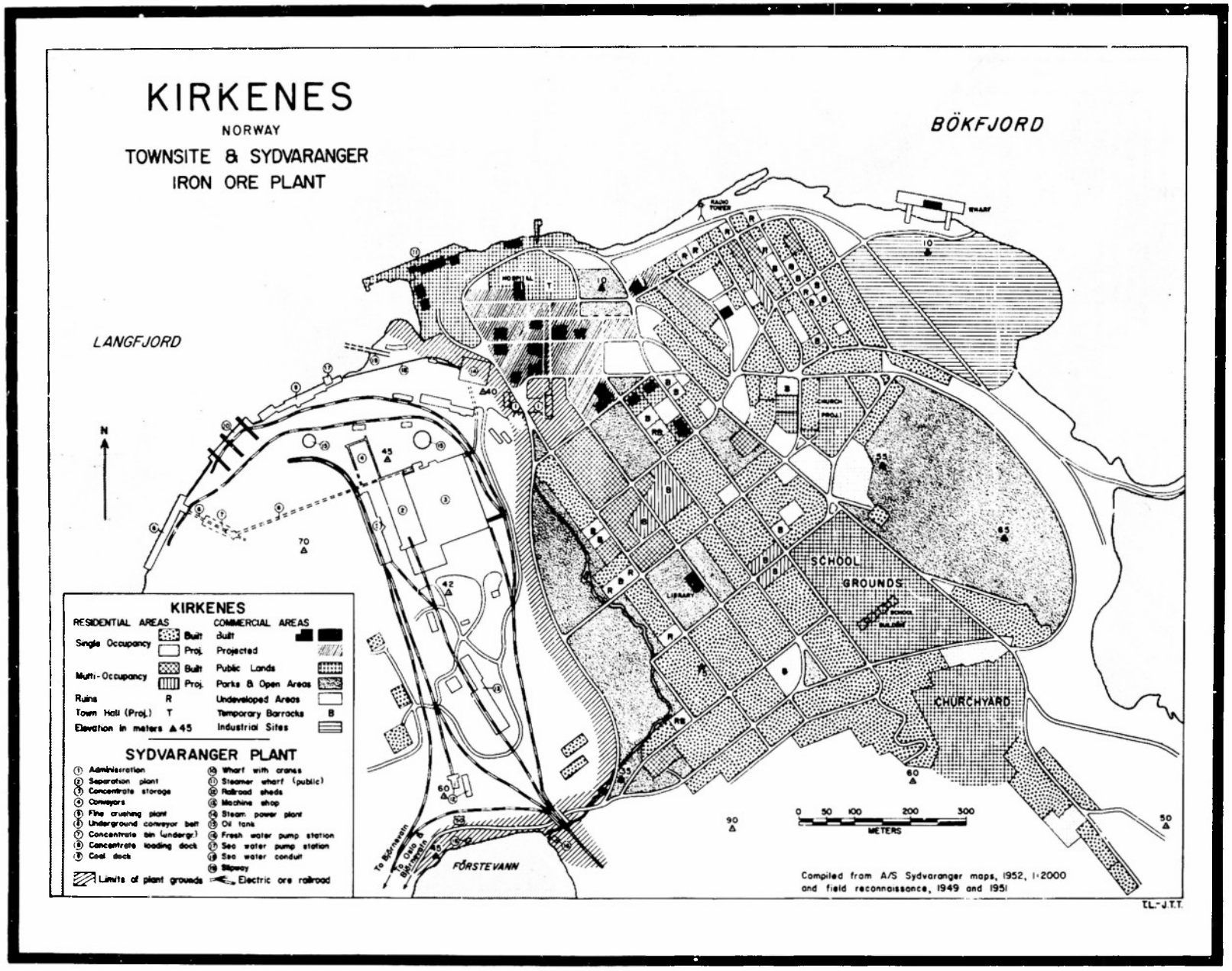
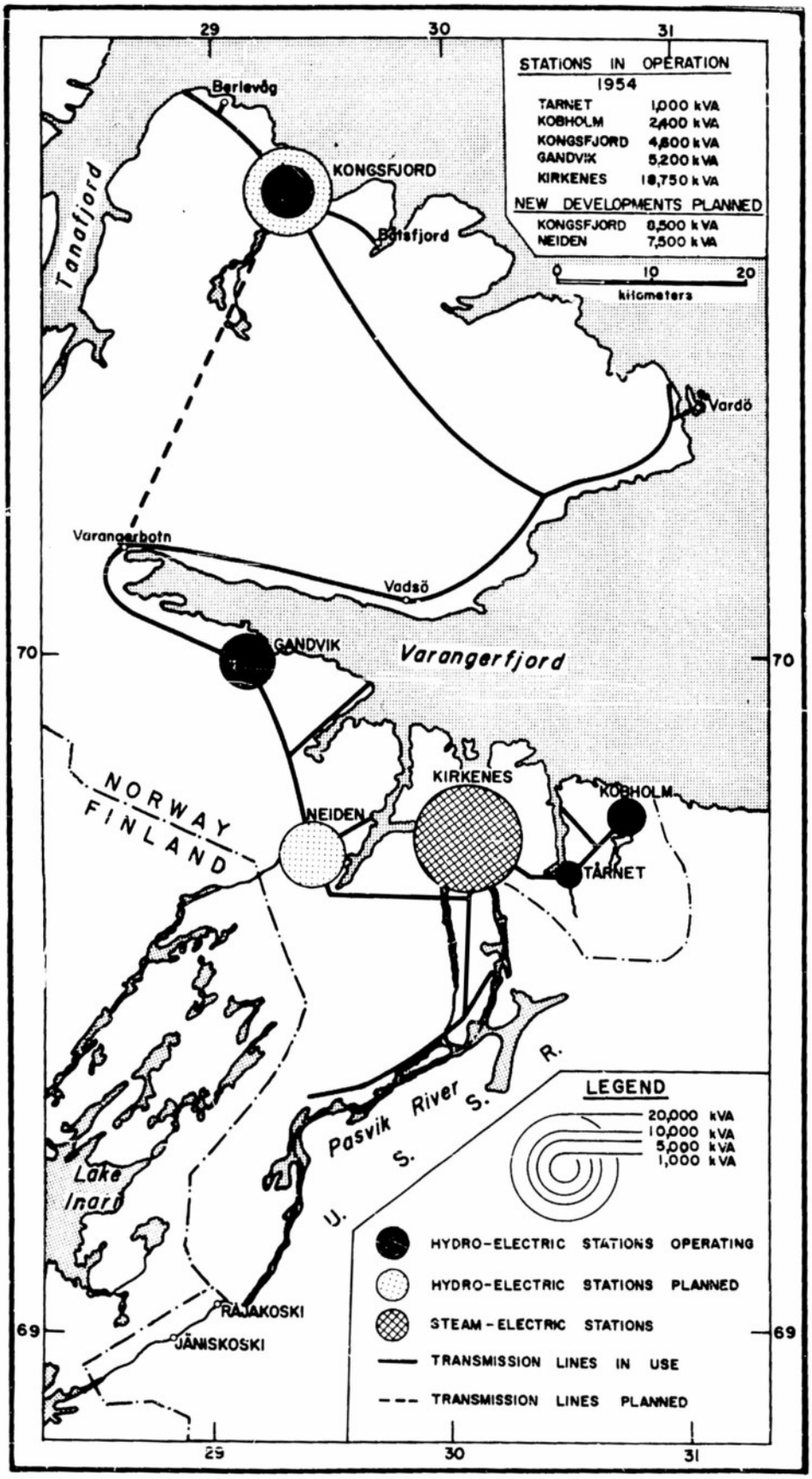

PRODUCTION AND EXPORT OF IRON ORE, KIRKENES, NORWAY.
THOUSANDS OF TONS
1,800
1,600
1,400
1,200
1,000
800
600
400
200
NO. OF WORKERS
1,300
1,100
900
700
500
300
100
Ore Mined
Concentrate
Concentrate Shipped
No. of Workers
(1940-1953)
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953

Fig. 7

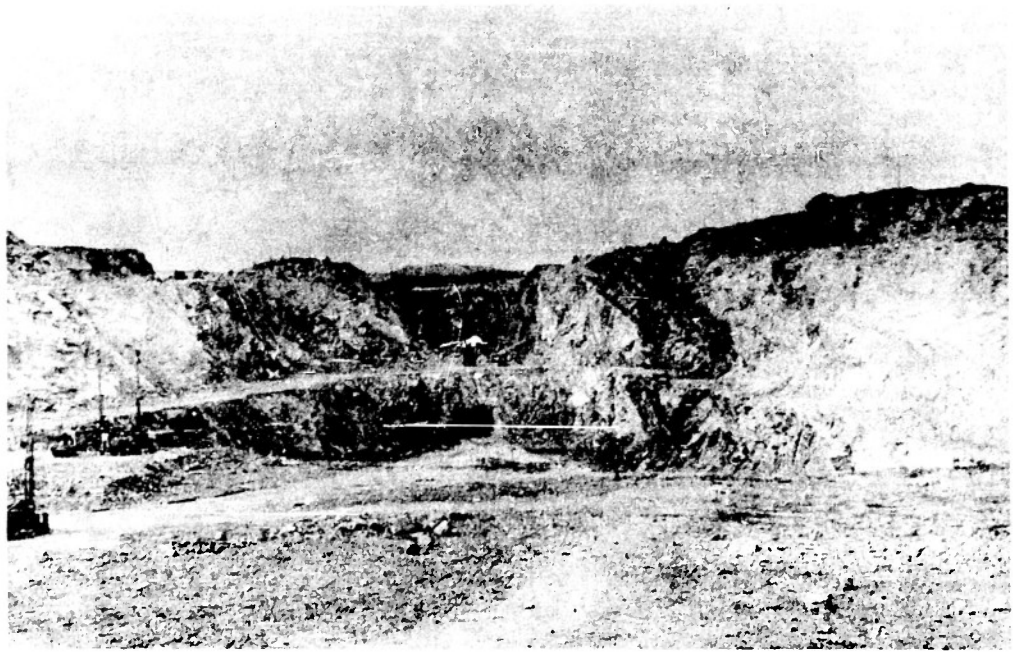

KIRKENES
NORWAY
TOWNSITE & SYDVARANGER
IRON ORE PLANT
BÖKFJORD
LANGFJORD
N
SCHOOL GROUNDS
CHURCHYARD
FÖRSTEVANN
To Bjørnevatn
To Oslo Bjørnevatn
0 50 100 200 300
METERS
Compiled from A/S Sydvaranger maps, 1952, 1:2000
and field reconnaissance, 1949 and 1951
T.L.-J.T.T.
KIRKENES
RESIDENTIAL AREAS
Single Occupancy Built Proj.
Multi-Occupancy Built Proj.
Ruins R
Town Hall (Proj.) T
Elevation in meters △45
COMMERCIAL AREAS
Built
Projected
Public Lands
Parks & Open Areas
Undeveloped Areas
Temporary Barracks B
Industrial Sites
SYDVARANGER PLANT
① Administration
② Separation plant
③ Concentrate storage
④ Conveyors
⑤ Fine crushing plant
⑥ Underground conveyor belt
⑦ Concentrate bin (undergr.)
⑧ Concentrate loading dock
⑨ Coal dock
⑩ Wharf with cranes
⑪ Steamer wharf (public)
⑫ Railroad sheds
⑬ Machine shop
⑭ Steam power plant
⑮ Oil tank
⑯ Fresh water pump station
⑰ Sea water pump station
⑱ Sea water conduit
⑲ Slipway
Limits of plant grounds
Electric ore railroad

Map 8

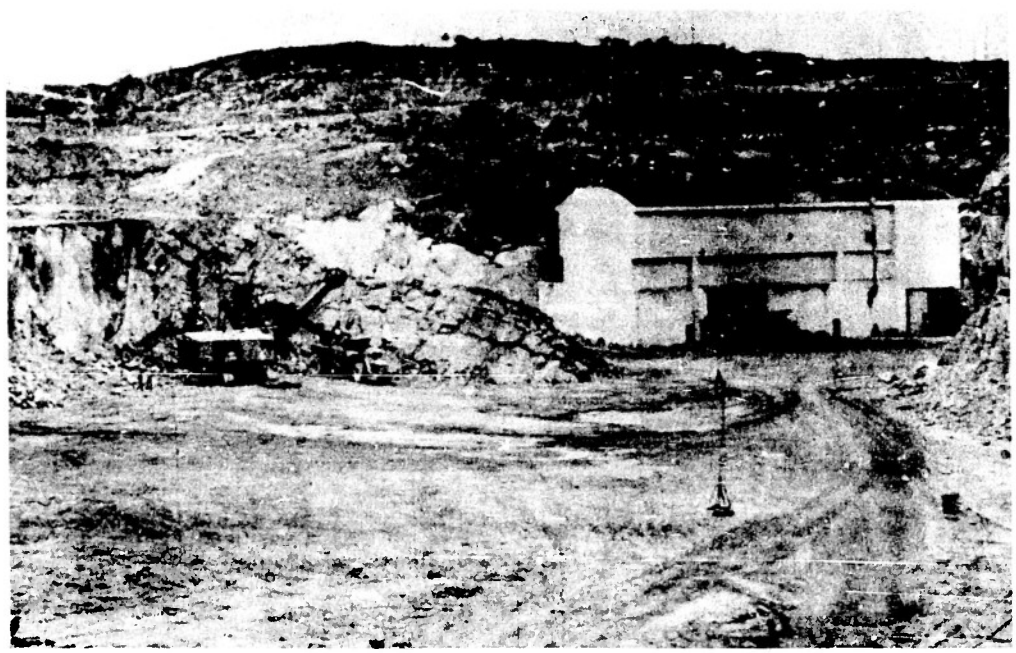
ELECTRICITY GENERATING STATIONS, EAST FINNMARK



Map 9



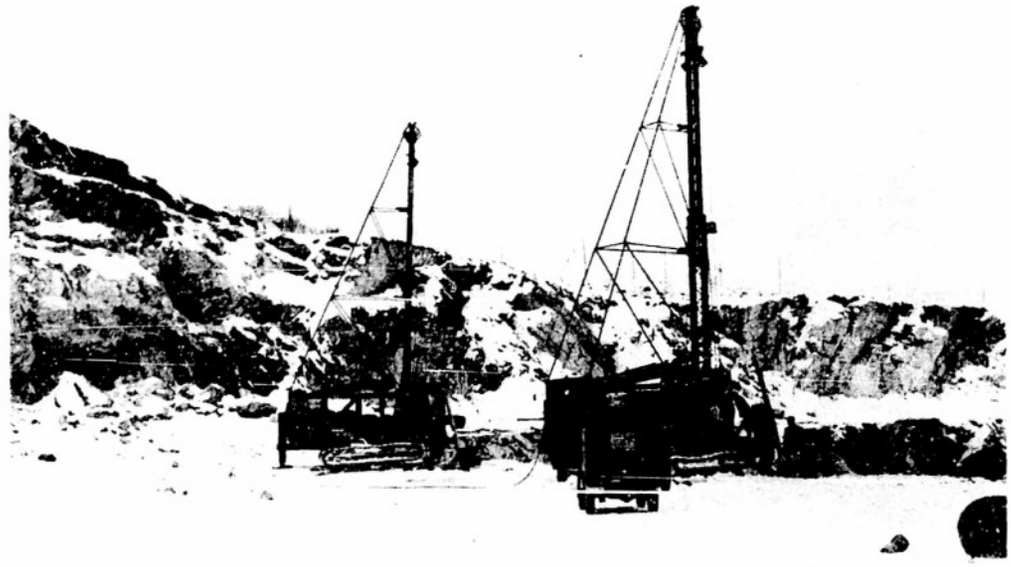
1. Typical section of east pit. The tunnel in the center leads to the north pit.



2. Primary crusher building in north pit

3. Electric shovel (4 1/2 cu. yd. cap.) loading broken ore into 35 ton truck.

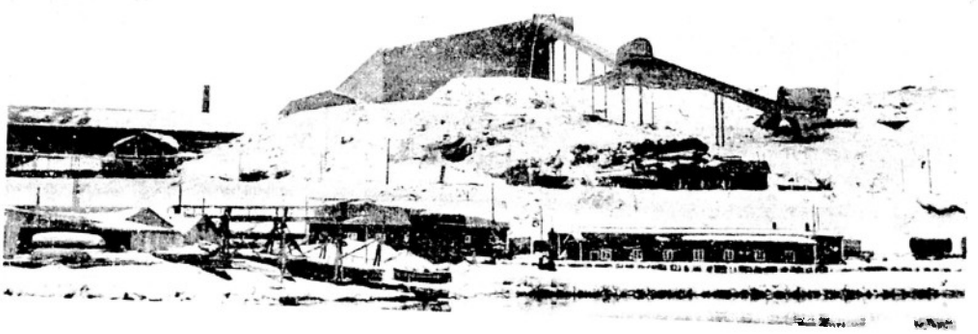
4. Ore being dumped from truck into 56" primary crusher.



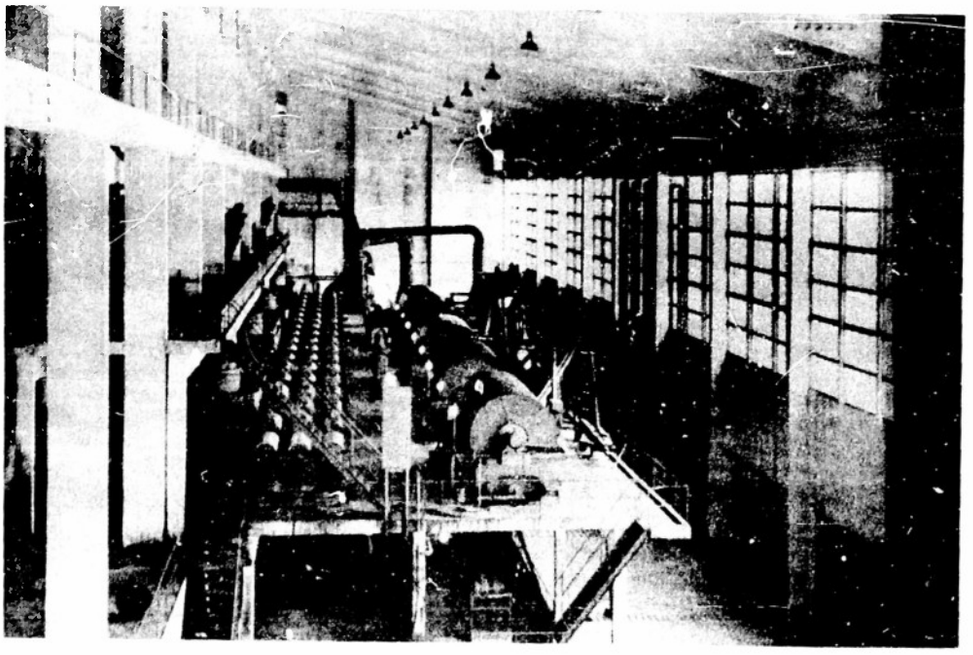
5. Blast-holes being made by 9" churn drills, using nickel alloy steel bits.

6. Bjønevatn village, located near open pit, during reconstruction.

7. Kirkenes ore plant during construction. Repair shops at left, concentrator at right.

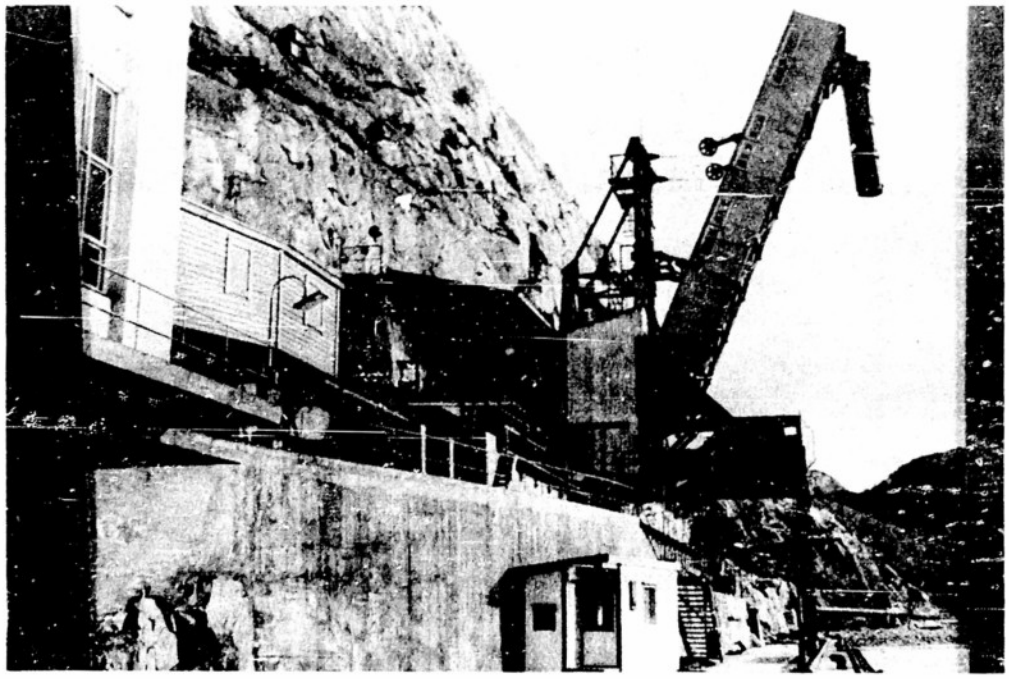


8. Kirkenes ore plant and enclosed conveyors seen from public wharf. Storage bin was excavated within hill at right.



9. Magnetic separation (18, 3-drum units) at left, with drum filters at right.

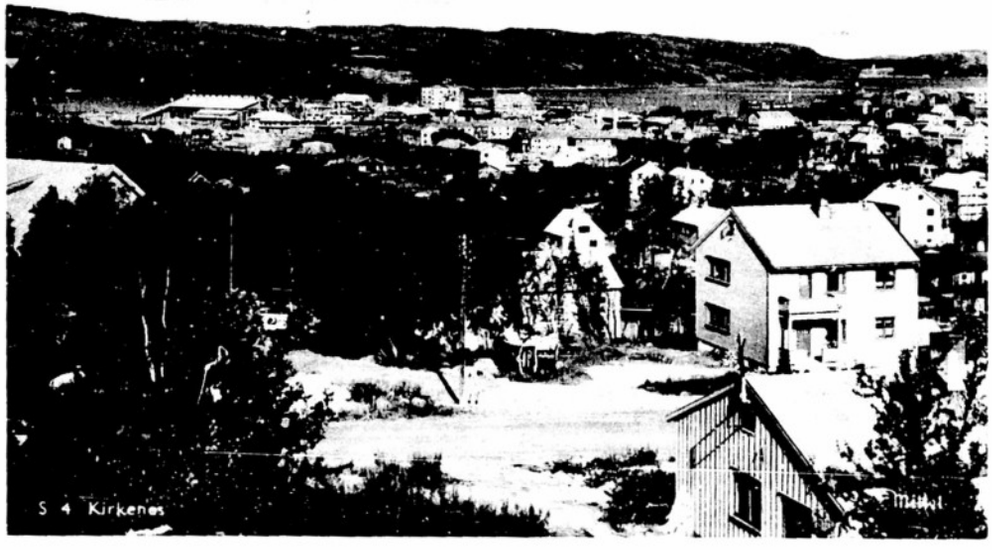
10. Kirkenes ore wharf on Langfjord seem from public quay. Pump house at left.



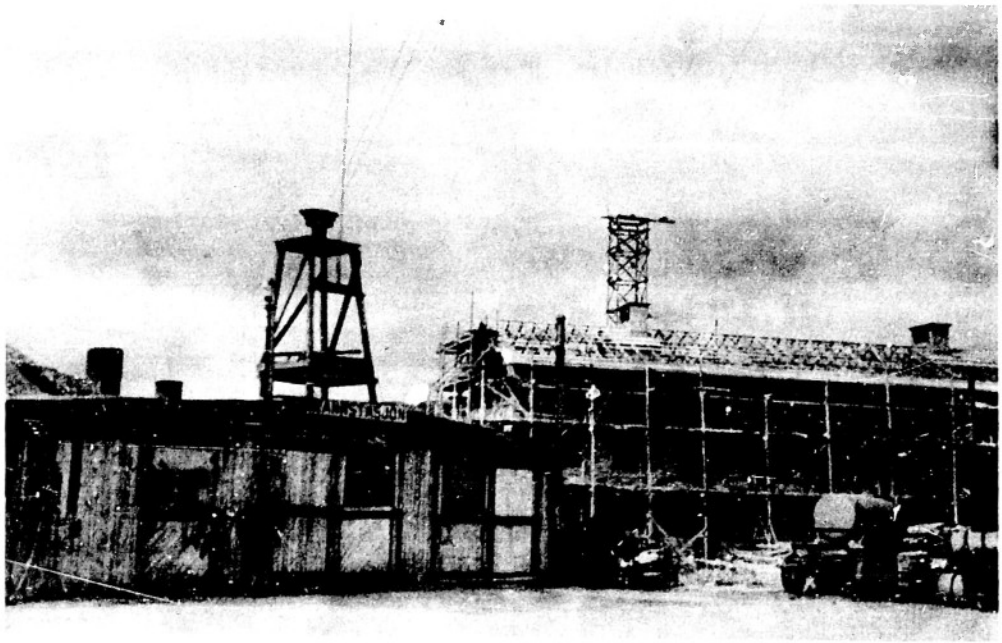
11. Kirkenes concentrate-loading quay, showing conveyor (raised) leading from storage bins to vessel.

12. Kirkenes public quay on Langfjord seen from ore plant. Channel to open sea is at left background.

13. Kirkenes, New houses rebuilt following wartime destruction. (looking northeast).



14. Kirkenes. View northwest to town center and Langfjord. Power house is prominent in left background.



15. Kirkenes. Temporary barrack (used as fire station) with new building in rear.

16. Kirkenes. Birches in small park (photo taken in late March.)

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